INVERSION OF REFLECTION AND SCATTERING DATA TO MEASURE SEA ICE THICKNESS

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LONG-TERM GOAL

The goals of this work are to develop and implement stable, mathematically sound methods to invert data on backscattering and reflection from sea ice at microwave frequencies to yield estimates of geophysically significant quantities such as thickness, the profile of brine volume vs. depth in the ice, and snow properties. By stable methods, we mean methods that are robust in the presence of noise and experimental uncertainties.

SCIENTIFIC OBJECTIVES

Our immediate objectives during the past year have been: (1) the application of our newly developed, causally stabilized layer stripping method, and results based on our method, to the inversion of broadband sea ice reflectivity data to observations acquired as part of the Sea Ice Electromagnetics ARI; and (2) and the refinement and extension of our methods based on what we learn from comparison with observations.

APPROACH

Our approach is via mathematical inverse theory and provably convergent results, in contradistinction to optimization methods for parameter inversion. The latter may result in plausible but erroneous parameter retrievals because of local, but not global, minima in a high-dimensional, abstract space in which the optimization takes place. Our approach has shown its worth by providing a valuable method for inversion of reflectivity data for ice thickness alone (when the full profile of dielectric properties is not required). Such a method could not have been found without the analytical insight resulting from a mathematically rigorous approach.

WORK COMPLETED

Our work during the past year has focused on application of our mathematical progress to experimental data from the CRRELEX experiment, including both indoor and outdoor laboratory data, and on contributions to group papers summarizing the ARI for a special issue of the IEEE Transactions on Geoscience and Remote Sensing.

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The indoor laboratory data we have worked with was supplied by S. Johnson (Univ. Utah), as the result of his work funded under the Sea Ice Electromagnetics ARI. The data come from a system of two planar layers over a basement, and consist of complex reflectivity measurements at a single angle of incidence and polarization over a bandwidth of 1-18 GHz. Our layering stripping algorithm performs very well on these data, recovering estimates of layer thicknesses and dielectric constants ingood agreement with those of Johnson (the latter are derived from an optimization-inversion technique, rather than from direct measurement).We have included these results in our contribution to the group paper on which Ken Golden is lead author.

The outdoor laboratory data we have used come from R. Onstott, and include 6 cases from the outdoor pond at CRREL with varying synthetic sea ice thicknesses ranging from 0 to 6 cm. These data are nadir reflectivities, but their phases are constrained to be linear functions of frequency (which would correspond to the response to a single, zero-thickness target at a given range). The frequency bands covered by the data are from 0.4 to 2.7 GHz continuously, with two additional bands separated by gaps. The highest frequency in the data is 11 GHz, which we would expect to yield roughly a 3 cm range resolution in the best case. Because the data do not include phase information needed for a full permittivity profile retrieval, we have applied our method for estimation of travel time ice thickness based on amplitude information alone. The results show a monotonically increasing ice thickness as we progress through the cases, but relatively low ratio of ice thickness to shortest wavelength in the data set complicates the objective estimation of thickness values. We are presently working to justify a particular objective estimation.

In addition, we have contributed a section on polarimetric estimation of sea ice thickness using synthetic aperture radar to the group ARI paper on which R. Kwok and S. Nghiem are lead authors.

IMPACT/APPLICATION

The problem of profile inversion (1-dimensional inverse theory) in lossy media is of very wide interest. The stable solution of this problem therefore is likely to influence seismology, ocean acoustics, non-destructive testing, as well as remote sensing. The realization that polarization information is useful in the lossy problem should also carry over to the elastic wave propagation/inversion problem. Our results, as well as methods, are therefore also of wide interest.

TRANSITIONS

We have begun to apply the insights gained in this work to problems of lidar retrievals in the atmosphere, and presently working to obtain ONR support in this area.

RELATED PROJECTS

As noted below, we are seeking to make a transition in this work to inverse problems occurring in lidar retrievals of atmospheric aerosol parameters.

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